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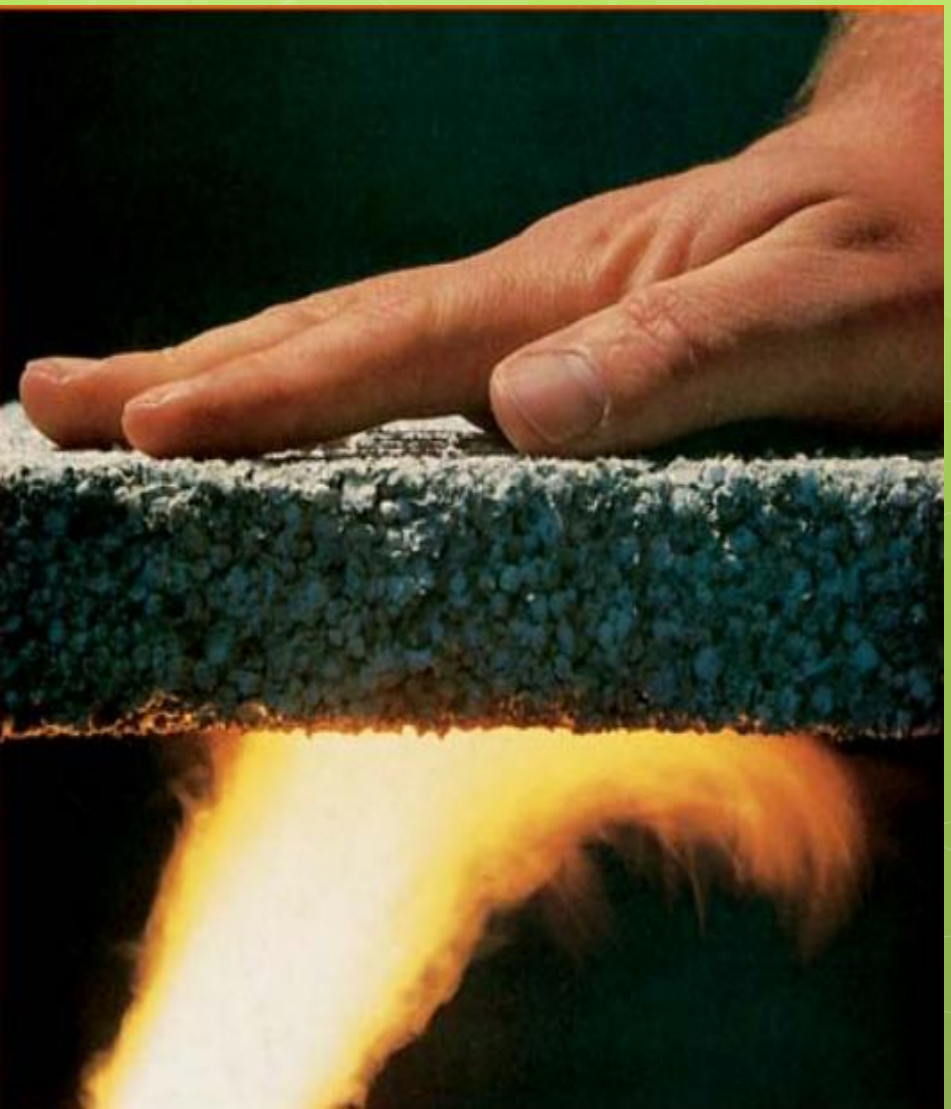
FACULITY OF ENG.SHOUBRA



CONCRETE AND FIRE

edited by omar elnaggar

أسماء الطلاب المشتركين

عمر فاروق السيد إبراهيم النجار	SEC: 6
عماد عبدالمنعم على عراقى خليفة	SEC: 6
عبدالله خالد محمد مختار	SEC: 6
صفى الدين صبحى على قنصوة	SEC: 5
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1. Introduction

- Reinforced concrete is considered a material that shows an acceptable resistance to high temperatures, which allows using concrete elements without the need of any additional protection. However, long periods of exposition of reinforced concrete to high temperatures introduce physical-chemical changes in its properties that lead to mechanical strength decay which produces losses in the safety of the structure

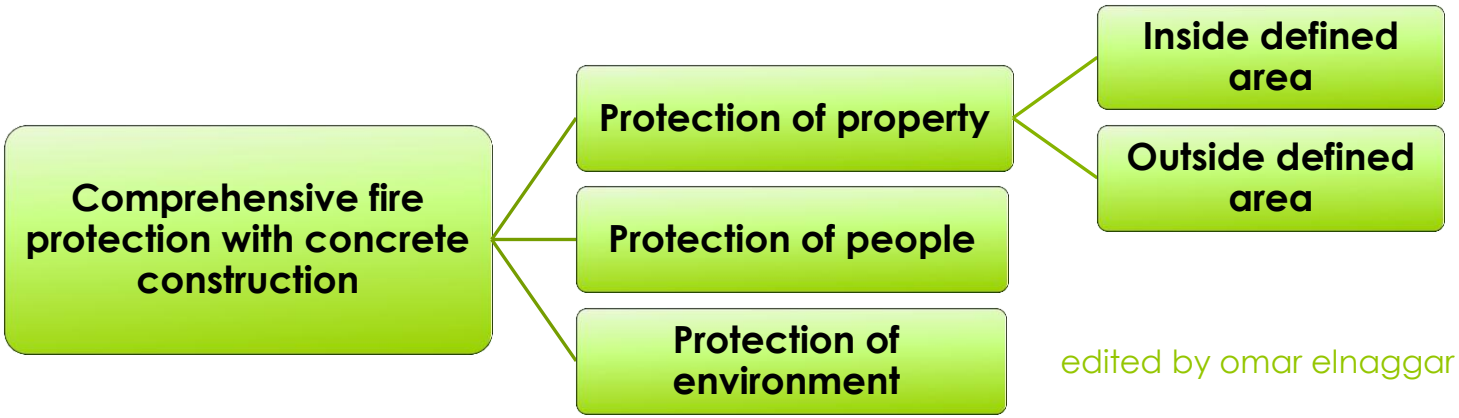
2. Concrete provides comprehensive fire protection

- Concrete does not burn, and does not add to the fire load
- Concrete has high resistance to fire, and stops fire spreading
- Concrete is an effective fire shield, providing safe means of escape for occupants and protection for firefighters
- Concrete does not produce any smoke or toxic gases, so helps reduce the risk to occupants
- Concrete restricts a fire, and so reduces the risk of environmental pollution
- Concrete can resist extreme fire conditions, making it ideal for storage premises with a high fire load
- Concrete's robustness in fire facilitates firefighting and reduces the risk of structural collapse
- Concrete is easy to repair after a fire, and so helps businesses recover sooner
- Concrete is not affected by the water used to quench a fire

❑ Structural fire protection measures must fulfill three aims :

- **Personal protection** to preserve life and health;

- **Protection of property** to preserve goods and other belongings both in residential or commercial units that have caught fire, and in neighboring properties. To this must be added substantial preservation of the building structures;
- **Environmental protection** to minimize the adverse effects on the environment through smoke and toxic gases as well as from contaminated water used for extinguishing fires.



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Summary of unprotected construction materials performance in fire

Unprotected construction material	Fire resistance	Combustibility	Rate of temperature rise across a section	Built-in fire protection	Repairability after fire	Protection for evacuees and firefighters
Timber	Low	High	Very low	Very low	Nil	Low
Steel	Very low	Nil	Very high	Low	Low	Low
Concrete	High	Nil	Low	High	High	High

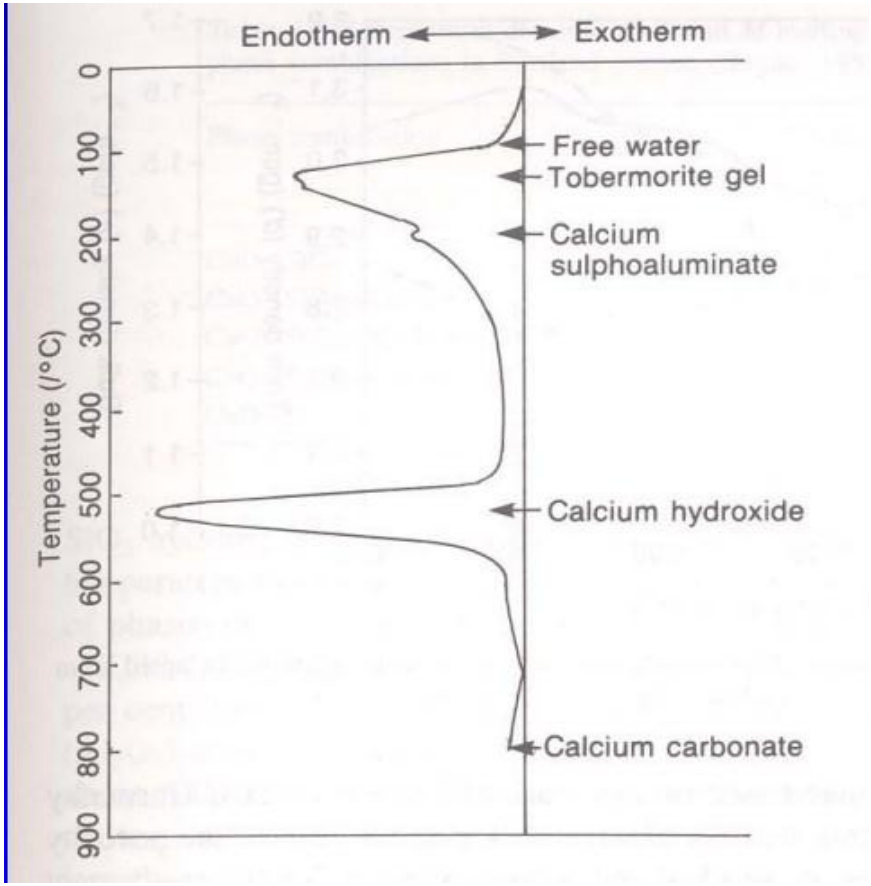
Requirements for fire safety and their relation to concrete

Objective	Requirement	Use of concrete
1. To **reduce the development** of a fire	Walls, floors and ceilings should be made of a non-combustible material	Concrete as a material is inert and **non-combustible**(class A1);
2.To ensure **stability** of the loadbearing construction elements over a specified period of time	Elements should be made of noncombustible material and have a high fire resistance.	Concrete is non-combustible and due to its low thermal conductivity most of its **strength is retained** in a typical fire.
3.To limit the generation and **Spread** of fire and smoke	Fire separating walls and floors should be non-combustible and have a high fire resistance.	In addition to the above, adequately designed connections using concrete **reduce the vulnerability to fire** and make full use of its structural continuity.
4.To assist the **Evacuation** of occupants and ensure the safety of rescue teams	Escape routes should be made of non-combustible material and have a high fire resistance, so they can be used without danger for a longer period.	Concrete cores are **extremely Robust** and can provide very high levels of resistance. Slipforming or jumpforming are particularly effective methods of construction.
5.To facilitate the **Intervention** of rescue parties (firefighters)	Loadbearing elements should have a high fire resistance to enable effective firefighting; there should be no burning droplets.	Loadbearing elements **retain their integrity** for a long time and concrete will not produce any molten material.

❑ Test which show concrete resistance to fire(play video)

3. Behavior of the hardened cement paste

- Loss of evaporable water (Begins around 105oC)
- Decomposition of C-S-H (C-S-H →β-C2S, β-CS and Water)
- Dehydration of CH (500 -600)oC& (CH →CaO and water)
- Increase in porosity
- Destruction of C-S-H at 900oC



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4. Behavior of the Aggregates

- Aggregates subjected to heat during their formation perform better than siliceous aggregates
- Siliceous aggregates contain quartz which undergoes endothermic crystalline transformation as temperature increases
- Carbonate aggregates calcine from 600-900oC during fire driving off CO2
- Most aggregates expand at high temperatures

5. Concrete's performance under high temperatures

- **Concrete does not burn:**
  - ✓ There is no way in which concrete can contribute to the breakout and spread of fire or add to the fire load
- **Concrete is a protective material:**
  - ✓ Concrete has a high degree of fire resistance and, in the majority of applications, can be described as fireproof when properly designed. Concrete is a very effective fire shield. The mass of concrete confers a high heat storage capacity. Also its porous structure provides a low rate of temperature rise across a section. These properties result in a low rate of temperature rise that enables concrete to act as an effective fire shield.

- **Spalling:**
  - ✓ Spalling is part of concrete's normal response to the high temperatures experienced in a fire. Therefore, for normal buildings and normal fires (e.g. offices, schools, hospitals, residential), the design codes like Eurocode 2 already include the effect of spalling for these applications. We use fibers to prevent.
- **Concrete is easier to repair after a fire:**
  - ✓ The majority of concrete structures are not destroyed in a fire, and so one of the major advantages of concrete is that it can usually be easily repaired afterwards, thereby minimising any inconvenience and cost.

Causes of Cracks:

- ✓ Different expansion rates of hardened cement paste and aggregates.
- ✓ Thermal gradient between inner and outer layers of concrete (rapid heating).
- ✓ Building up of vapor pressure in pore.

Concrete at elevated temperatures:

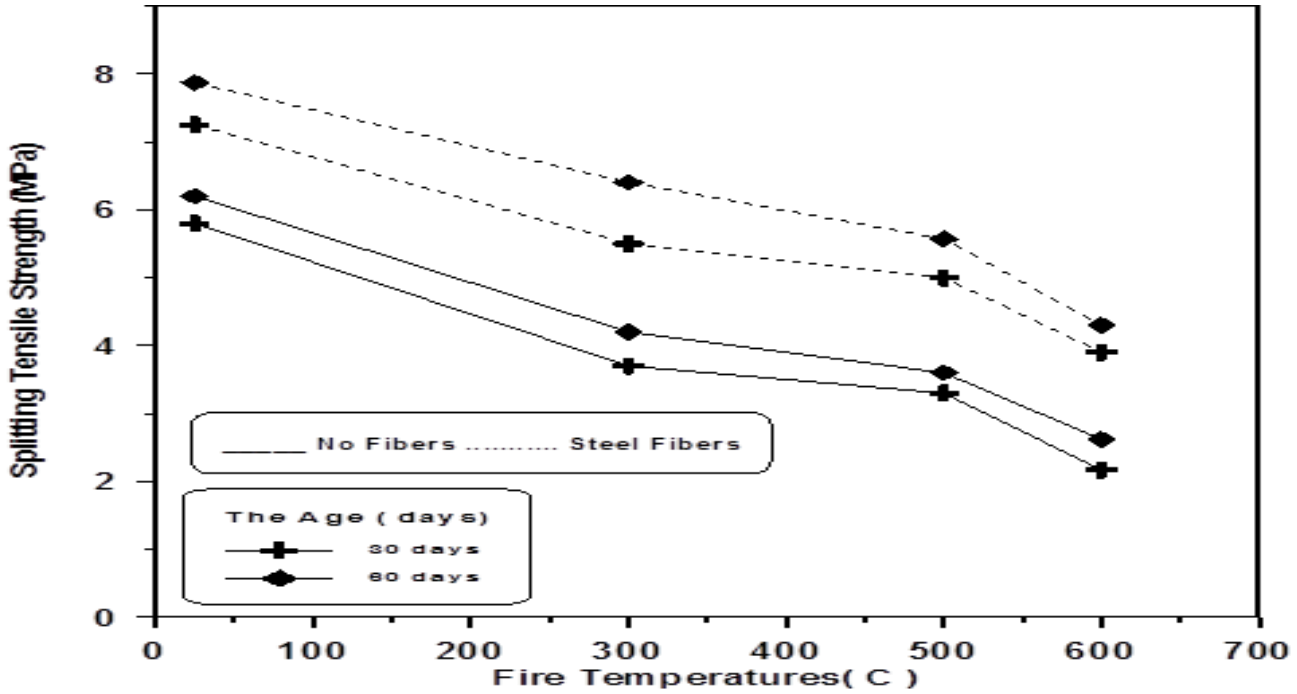
- 250 – 420 °C: Some spalling occurs
- 300 °C: Loss of strength begins
- 550 – 600 °C: Cement based materials experience creep and lose their load bearing capacity
- 600 °C: Greater than this temperature, concrete is not functioning at its full structural capacity
- 900 °C: Temperature of Flame

6. Thermal properties of concrete

- **Fire resistance of concrete is influenced by:**
  - tensile strength
  - aggregate type
  - moisture content
  - permeability
  - density
  - thickness

Tensile strength

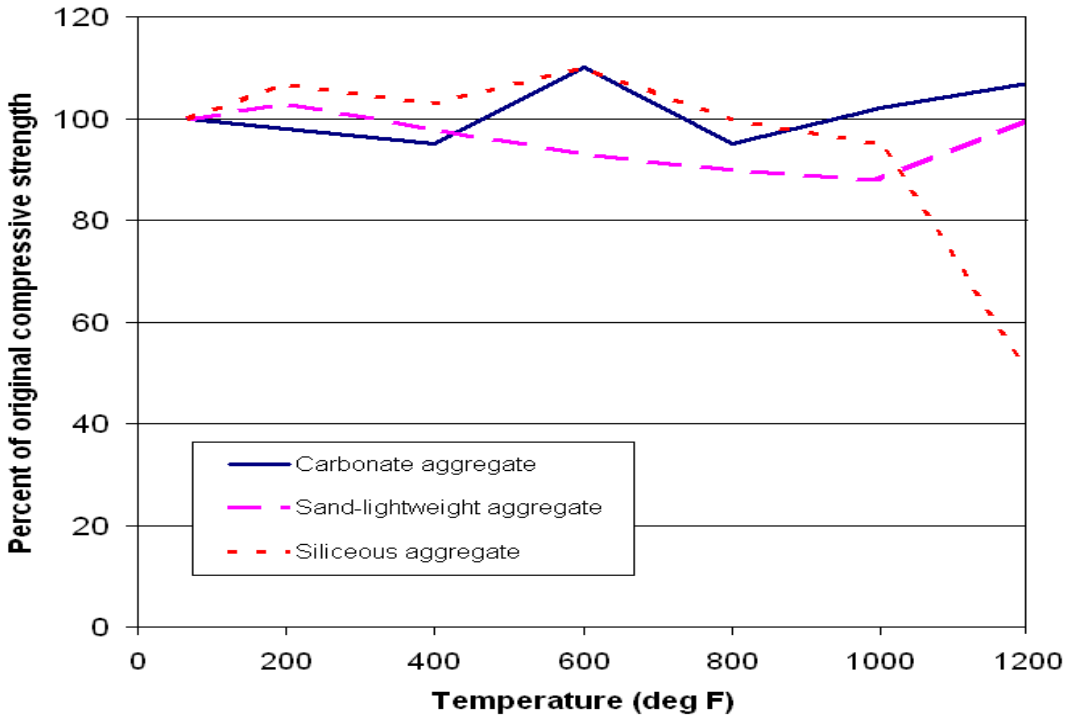
splitting tensile strength of high strength concrete decrease with increasing the fire temperature for plain and steel fiber reinforced concrete.



- The effect of fire flame on the splitting tensile strength of plain and steel fibers reinforced concrete at 1.0 hour period of exposure.

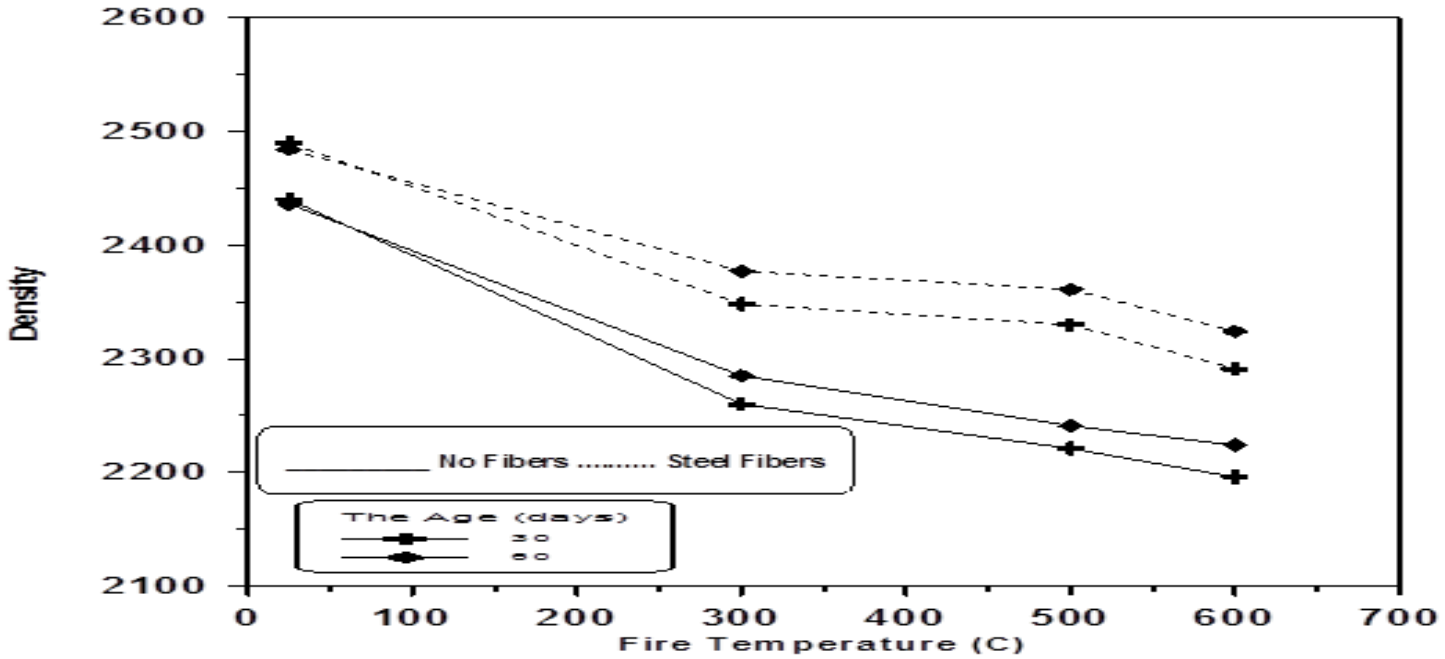
Aggregate type

Aggregate can amount to 60-80% of the total volume of concrete; therefore, the choice of aggregate directly impacts the performance of concrete during a fire.



Density

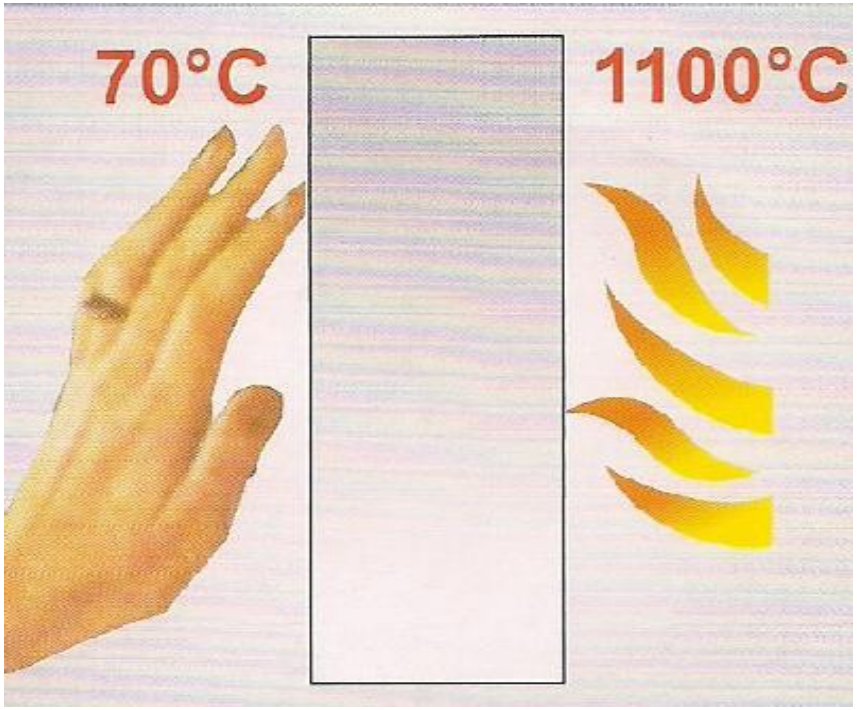
The density of high strength concrete decrease with increasing the fire temperature for plain and steel fiber reinforced concrete.



- The effect of fire temperatures on the density of plain and Steel fiber reinforced concrete at 1.0 hour period of exposure.

Effects of High Temperature on:

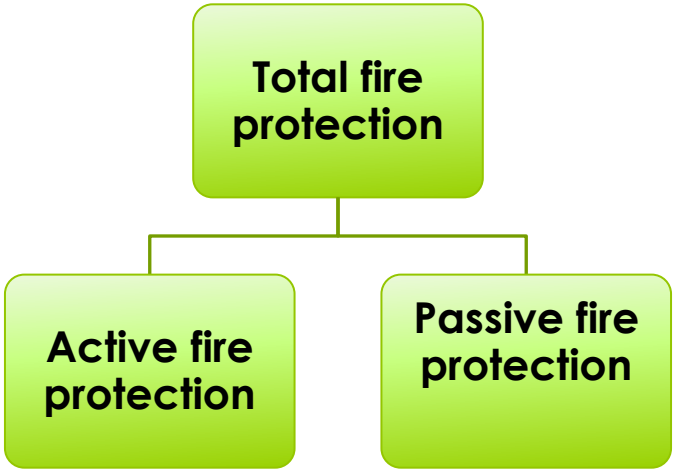
- Compressive strength
- Elastic modulus
- Creep
- Bond Strength



7. Repair

- Remove damaged layers of concrete and replace with fresh concrete
- Recuring
  - ✓ Regain post-fire strength due to rehydration of C-S-H as well as hydration of previously Unhydrated cement grains, reducing porosity

❑ Balanced Design



Active Fire Protection

Smoke detectors
Sprinklers
Duct detectors
Fire alarms

Passive Fire Protection

Fire rated walls
Fire rated floors
Fire rated separations

Fire Resistance

The term "fire-resistance" designates the ability of a laboratory-constructed assembly to contain a fire in a carefully controlled test setting for a specified period of time.

Structural Design Load

- Live Load + Dead Load + FIRE

Goal of Fire Resistance Structures

- Maintain structural stability
- Reduce spread of fire
- Experience total burnout without collapse

❑ Concrete protects before and after the fire

- This may come as a surprise because global data on the cost of fire protection indicates that around 2 to 4% of construction costs are typically spent on fire protection measures, but with concrete fire protection is an integral and therefore complimentary benefit. In fact, concrete has a reserve of fire security that stays effective even after change of use, or if the building is altered.
- Concrete's fire safety properties do not change over time and remain consistent without incurring maintenance costs. The inherent fire resistance properties of concrete elements enable them to fully satisfy fire protection requirements economically; they also make it somewhat future-proof to minor changes in fire safety legislation. However, if a fire does occur, investment in a concrete building will really make sense.

8. Improving Performance

- Refractory concrete
  - ✓ High alumina cement and/or aggregates used
  - ✓ Pozzolans
- Polypropylene fibers
- Rubber

8. References

- [1] Haack, A. Catastrophic Tunnel Fires - What have we learnt? International symposium on catastrophic tunnel fires (CTF). Boras, Sweden, 2003.
- [2] Jansson R. and Bostrom L. Experimental study on the influence of polypropylene fibres on materi properties and fire spalling of concrete. fib task group 4.3 workshop "Fire design o concrete structures from materials modelling to structural performance". Coimbra, Portugal, 2007.
- [3] Kalifa, P., G. Chéné, and Gallé C. "High-temperature behaviour of HPC with polypropylene fibres: From spalling to microstructure." Cement and Concrete Research 31(10): 1487-1499, 2001.
- [4] Schrefler, B. A., G. A. Khoury, Gawin D. and Majorana C.E. "Thermo-hydro-mechanical modelling of high performance concrete at high temperatures." Engineering Computations 19(7-8): 787-819, 2002.
- [5] Ulm, F.-J., P. Acker, and Levy M. "The ``Chunnel'' Fire. II: Analysis of Concrete Damage." Journal of Engineering Mechanics 125(3): 283-289, 1999.
- [6] P. Kalifa, G. Chene, C. Galle, High-temperature behaviour of HPC with polypropylene fibers. From spalling to microstructure, Cem.Concr. Res. 31 (2001) 1487 – 1499.
- [7] Khoury G.A. and Anderberg Y. Concrete spalling - Review, Fire Safety Design, 2000.
- [8] Bazant, Z. P., G. Cusatis, and Cedolin L. "Temperature Effect on Concrete Creep Modelled by

  Microprestress-Solidification Theory." Journal of Engineering Mechanics 130(6): 691-699,